U.S. Fish and Wildlife Service
Office of Subsistence Management
Fisheries Resource Monitoring Program

Eastern North Slope Dolly Varden Genetic Stock Identification and Stock Assessment

Annual Report for Study 01-113

Tim Viavant

Alaska Department of Fish and Game
Division of Sport Fish
1300 College Road
Fairbanks, Alaska 99701-1599

June 2004
Alaska Department of Fish And Game

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

This report summarizes work conducted in 2003, part of multiple year study of Dolly Varden *Salvelinus malma* in eastern Alaska drainages of the Beaufort Sea, designed to characterize population structure and develop stock assessment techniques. Six replicate aerial surveys of the overwintering aggregation in a 28 km index area of the Ivishak River were conducted to estimate variability in counts as a means of evaluating the efficacy of this method. Five counts were conducted under good or excellent conditions. Counts were very similar and ranged from 2,252 to 2,948 (CV=0.05). Abundance and size composition of Dolly Varden of the overwintering aggregation for the same section of the Ivishak River were estimated using mark-recapture techniques. Estimated abundance of Dolly Varden >220 mm FL in 2003 was 9,259 fish (SE=1,156). This estimate was substantially smaller than estimates obtained in 2002 (21,639) and 2001 (49,523). Fish ranged in size from 220-705 mm FL and the length frequency distribution was distinctly bimodal. Twenty-two non-spawning fish in the Anaktuvuk River and 18 spawning-condition fish in the Ivishak River were implanted with radio tags in September 2003 to document overwintering locations in 2004. Those fish will be located in April 2004 and results will be presented in the final project report. Thirty-seven discrete spawning locations were identified in the upper Ivishak River on September 14, 2003. Many of the locations were similar to areas documented in previous years. However, a large number of new locations were documented in areas upstream of the most upstream location previously identified. During September 2003, tissue samples from spawning adults or pre-smolt juveniles were added to the collections from the Ribdon, Anaktuvuk, and Saviukviak rivers as part of an effort to collect baseline mitochondrial DNA genetic markers for various North Slope populations. In addition, a mixed-stock sample of 500 non-spawning overwintering adults was collected from the Ivishak River during the mark-recapture abundance estimate. This mixed-stock sample will be used to compare against stock-specific samples for evaluating genetic stock identification feasibility. The results of the genetic studies will also be presented in the final project report.

Key words: Dolly Varden, mitochondrial DNA, North Slope, overwintering abundance, *Salvelinus malma*, spawning location, subsistence fishery.

Citation: Viavant, Tim. 2004. Eastern North Slope Dolly Varden Genetic Stock Identification and Stock Assessment. Federal Subsistence Fishery Monitoring Program Annual Report for Study 01-113. Alaska Department of Fish and Game, Division of Sport Fish, Fairbanks, Alaska.

INTRODUCTION

This is the third annual progress report of a three year study of anadromous Dolly Varden on the North Slope of the Brooks Range, and includes results of the stock assessment and spawning location portions of the third year of the study, as well as the results of the overwintering location portion of the second year of the study. Results of all portions of all three years of the study and results of genetic stock identification feasibility will be included in a final report in March of 2005.

Information regarding the first year of the study is reported in the first annual progress report (Viavant 2002), results from the second year of the study are reported in the second annual progress report (Viavant 2003), and information from a feasibility study done prior to the full three year study is reported in the final report of the feasibility study (Viavant 2001).

Anadromous Dolly Varden *Salvelinus malma* are widely distributed in the Beaufort Sea drainages of the North Slope of the Brooks Range between the Colville River and the Canadian border (Figure 1). Fish from these stocks are an important subsistence resource in the communities of Kaktovik, Nuiqsut, and Anaktuvuk Pass (Craig 1987; Pedersen 1990). These same stocks of fish also contribute to sport fisheries along the Dalton Highway and in the Arctic National Wildlife Refuge and Gates of the Arctic National Park.

Much of the habitat that these fish depend on is also located within areas with significant potential for future resource development. Although their distribution is widespread among North Slope drainages, the extent of their distribution within drainages and among drainages has not been completely cataloged. Because of their complex life history, these fish are highly dependant on critical spawning and overwintering habitat that is probably limited (Craig 1989; Krueger et al. 1999), and has also not been completely cataloged.

These fish have complicated migration patterns, and although some research has been done on life history and distribution, very little work has been done on stock assessment. Because resource development on the North Slope is often dependent on the use of large quantities of gravel and water, exploration and development is likely to have significant effects on these subsistence resources. These effects can only be mitigated with sufficient knowledge of the timing and locations of overwintering and spawning habitat needs of these populations.

This project is intended to investigate the validity of using aerial surveys as a stock assessment tool. The project will estimate the precision of replicate aerial surveys of overwintering aggregations, and determine the relationship between aerial survey counts and mark-recapture abundance estimates of the same overwintering aggregations.

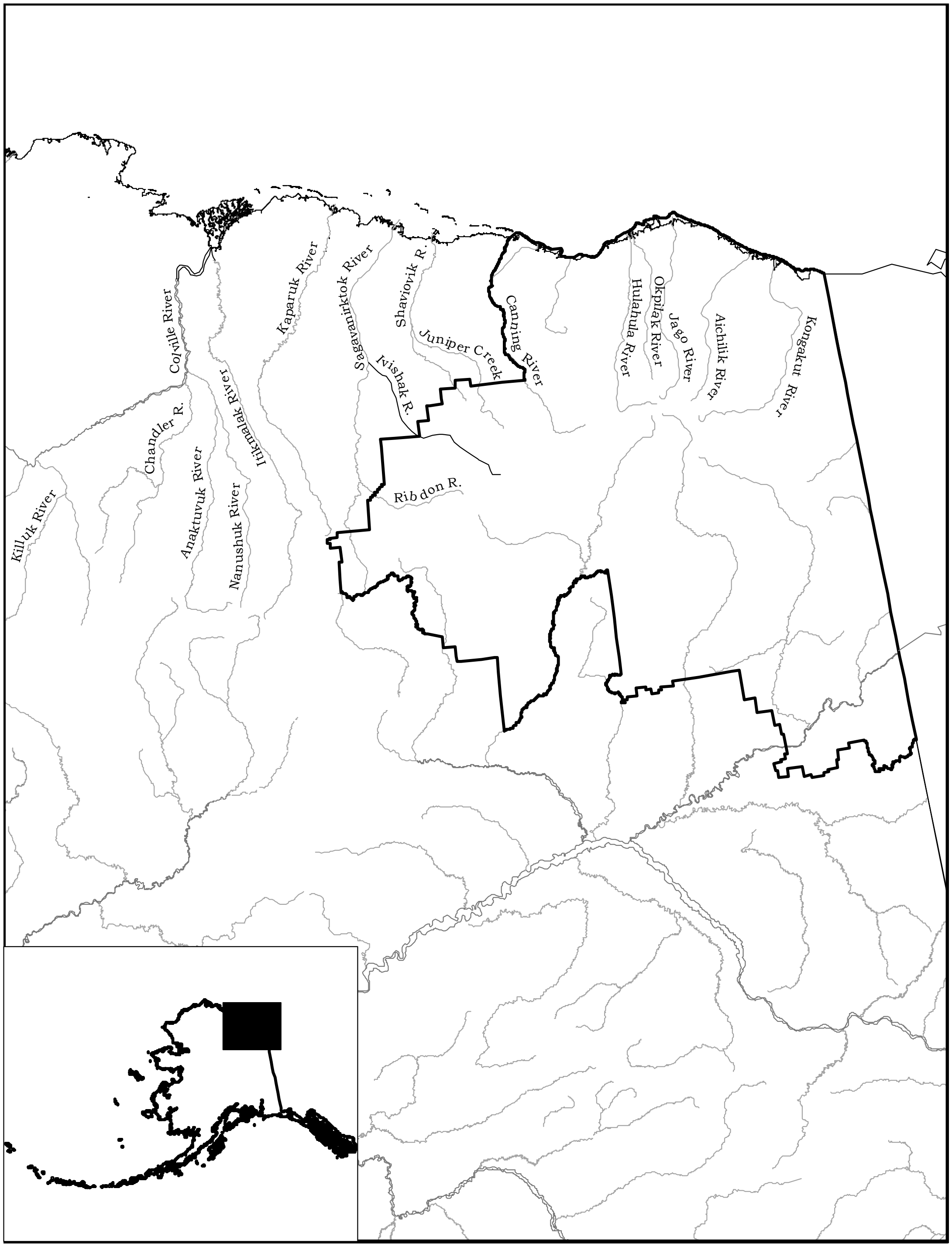

Figure 1.-Map of the eastern North Slope of the Brooks Range and coastal plain showing major drainages containing anadromous Dolly Varden and the boundary of the Arctic National Wildlife Refuge.

The project is also intended investigate the feasibility of using genetic stock identification to evaluate the stock composition of subsistence harvests. This will be done by collecting stock-specific mitochondrial DNA genetic samples from major spawning stocks that contribute to subsistence fisheries. If these spawning stocks show sufficient genetic separation from one another, similar genetic samples taken from subsistence harvests could be used to estimate the stock contribution of different spawning stocks to those harvests. The project will also verify known spawning and overwintering locations, and catalog and map new critical spawning and overwintering habitat.

OBJECTIVES

Overall Project Goal:

Characterize the population structure of Dolly Varden using mitochondrial genetic markers and test the performance of the genetic baseline to determine the potential for stock composition estimation of mixed stock subsistence harvests.

Year Three Objectives:

1) Estimate the variability of replicate aerial surveys of the overwintering aggregation (within a fixed 25 km area) on the Ivishak River conducted by the same observers under similar conditions during the same time period.

2) Estimate the abundance and size composition of Dolly Varden in the overwintering aggregation (same geographic area as objective 1) on the Ivishak River such that the abundance estimate is within 20% of the true value 90% of the time.

3) Identify new and verify known overwintering locations on the Anaktuvuk River and collect GIS mapping data for all verified and new locations such that the power to detect up to five overwintering locations comprising 100% of the locations used is at least 95%.

4) Identify new and verify known spawning locations on the Aichilik, Marsh Fork, and Kavik rivers and collect GIS mapping data for all verified and new locations.

METHODS

Aerial Survey Variability Estimation

Six replicate aerial surveys of a 28-km index area of the Ivishak River (Figure 2) were conducted from September 17-23, 2003. One of the six counts was not included in the analysis because survey conditions (visibility) were poor on that date. Counts were conducted from a helicopter by two observers, each counting only the fish present on one side of the river. Each observer counted the same side of the river during each survey. In portions of the river where multiple channels existed, the main channel with the majority of the fish present was marked and counted. Although all channels were not counted, the same marked river channels were counted during each survey. These replicate counts were conducted after upriver migration was judged to be essentially complete, based on aerial surveys that determined the absence of new fish migrating upstream from below the 28-km index area. This judgment was based on the presence of less than 10% of the number of fish counted in the assessment area present in the 10-km reach of river immediately below the 28-km index area.

The index area counted was divided into three subsections, corresponding to the subsections used in the concurrent mark-recapture estimate, and counts were subtotaled for each subsection. To eliminate conscious or unconscious bias during counts, replicate counts were conducted with the face plates of the tally counters covered, and the totals recorded by the helicopter pilot, so that the observers were not aware of their individual section or daily total counts until after all six replicate counts were complete. For each year of the study, the summed average aerial count was calculated as the mean of the five summed (over sections and observers) average counts from the replicates used in that year.

Mark-Recapture Abundance Estimation

A mark-recapture abundance estimate of this same aggregation (the same 28 km index area divided into the same subsections) was conducted using the Bailey modification of the Petersen two-event model for closed populations (Seber 1982). Adult fish were captured using beach seines, measured, and marked with a small fin-clip and a partial opercular punch. Fish were generally sampled along the navigable channels of the river which closely corresponded to the channels counted during aerial surveys. However, some sampling was conducted in the off-channel areas. Fish were marked during a seven day period (September 14-20), and were recaptured by a second crew during a seven day period that began after a two-day hiatus to allow for marked and unmarked fish to mix.

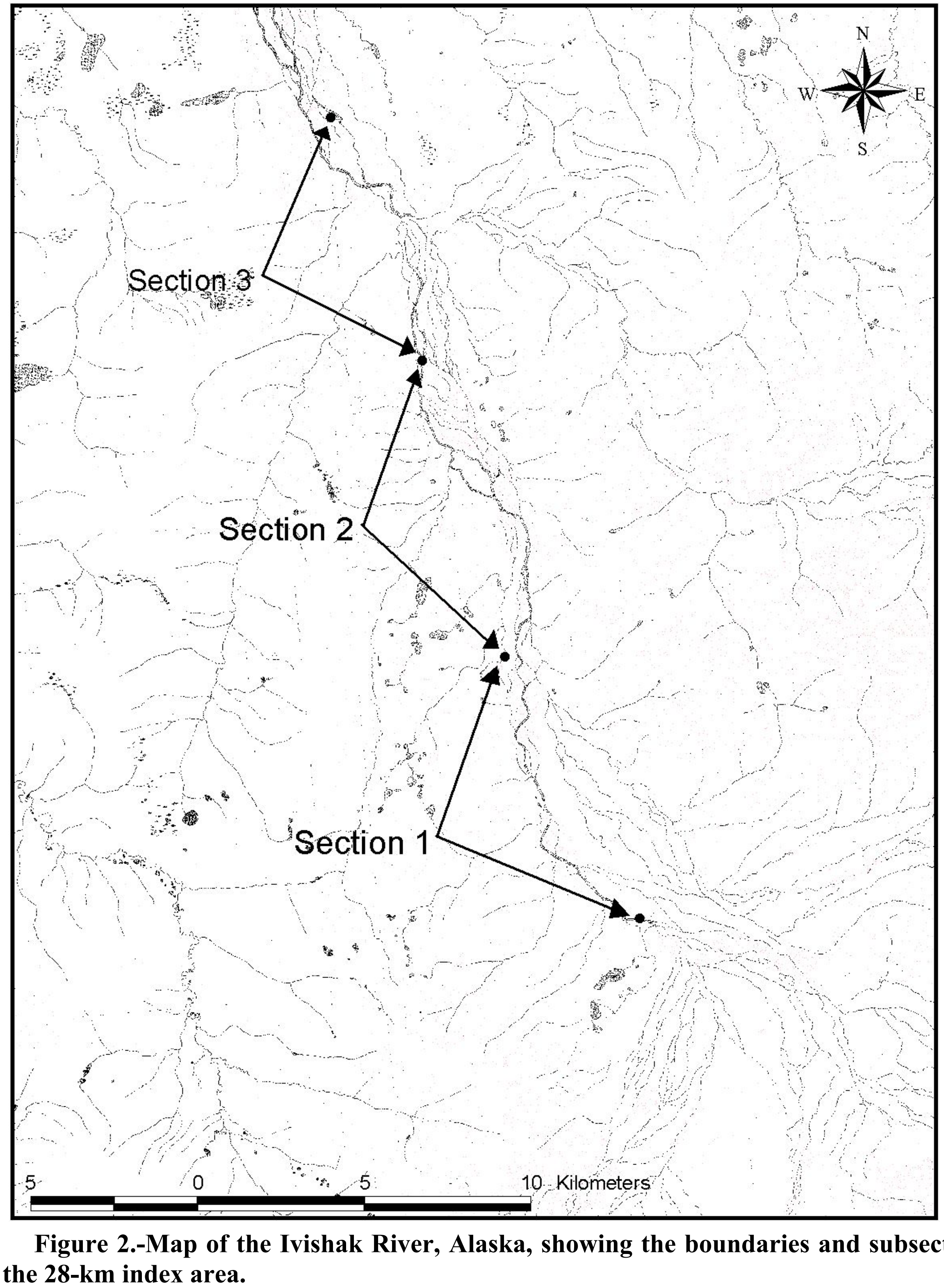

Figure 2.-Map of the Ivishak River, Alaska, showing the boundaries and subsections of the 28-km index area.

In order to evaluate fish movement during the experiment, the 28-km index area was divided into three approximately equal subsections prior to the marking event. Fish were given different fin clips depending on capture section to evaluate movement. Length, date, fin clip, and stream section were recorded for each fish captured. Data from the mark-recapture portion of the study were recorded on tagging length mark-sense (optical scan) forms. All Dolly Varden captured were measured to the nearest 5 mm from snout to tail fork. A detailed description of sampling and data analysis methods for the mark-recapture abundance experiment are found in Appendix A.

Radiotelemetry

Twenty-two non-spawning fish were surgically implanted with radio tags on the Anaktuvuk River September 19, 2003, in order to identify specific overwintering locations during April, 2004. Originally, 40 radio tags were to be implanted, but deteriorating weather conditions prevented completing implanting all radio tags, and weather and helicopter problems prevented any further opportunity to return to the Anaktuvuk River to complete implanting the remaining radio tags. Therefore, the remaining eighteen radio tags were implanted into pre-spawning Dolly Varden captured in the upper Ivishak River, about 10 km upstream of Section 3 (Figures 2 and 3) on September 19, 2003.. These radio-tagged fish were located from the air on September 22 and 24, 2003, to determine whether spawning fish moved downstream into the index area during the mark-recapture experiment. Dolly Varden carrying radio tags implanted during 2002 were also located on September 22 and 24, 2003. As will be done for radio tagged Dolly Varden in the Anaktuvuk River, radio tagged Dolly Varden in the Ivishak River will be located during April 2004 to identify overwintering sites. GPS (latitude/longitude) coordinates were recorded for all fish located.

SPAWNING AND OVERWINTERING LOCATIONS AND GENETIC STOCK IDENTIFICATION SAMPLING

During 2003, spawning locations were identified or verified in the Ivishak River by aerial and ground surveys, and all recorded locations were verified by on-the-ground capture and examination of fish to ensure that fish were in spawning condition. Fish on spawning locations were captured with both hook-and-line and seine. GPS coordinates were recorded for all verified spawning locations. These coordinates were entered into a GIS (geographic information system) database overlaid with USGS 1:63,000 maps. For each location, the approximate number of fish observed and the date observed were recorded.

Stock-specific genetic samples of adult fish in spawning condition and pre-smolt juveniles were collected during September, 2003, from the Ribdon and Saviukviak rivers. Attempts to collect stock-specific genetic samples from the Hulahula River during August were unsuccessful due to weather conditions which prevented access. A mixed-stock sample of 500 adult, non-spawning

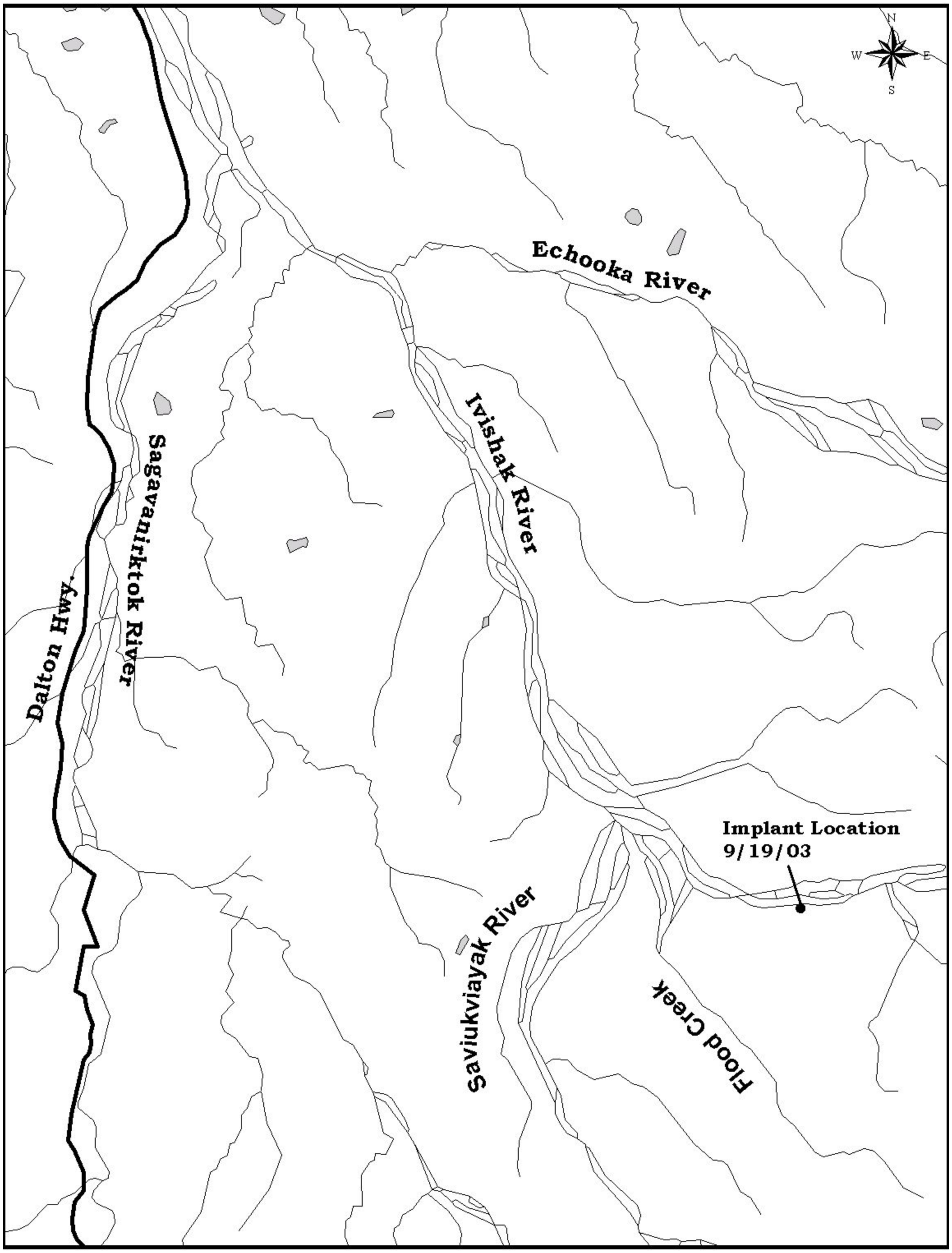

Figure 3.-Radio-tag implant location of spawning-condition Dolly Varden in the Ivishak River, Alaska, September 19, 2003.

fish were collected from the overwintering aggregation in the Ivishak River during the 2003 mark-recapture experiment. Fin clips were stored in individual vials of 90% ethanol. Samples were delivered to the US Fish and Wildlife Service (USFWS) Fish Genetics Lab at 1011 East Tudor Road, Anchorage for genetic analysis.

DNA was extracted from Dolly Varden from all drainages sampled to date for this project. DNA from these samples specific for eight microsatellite loci (*Sma-3*, *5*, *9*, *10*, *17*, *21*, *22*, and *24*) was amplified via polymerase chain reaction. In conjunction with study 01-136, additional primers from archived libraries developed through studies 00-011 and 00-001 and other *Salvelinus* studies have been screened to increase the number of loci used in the population surveys. The full analysis from these genetic samples will not be completed until after the 2004 sampling season, when all baseline and mixed stock samples are available for analysis. The results of all genetics work related to genetic stock composition feasibility will be reported in the final report of this study in March of 2005.

RESULTS

AERIAL SURVEY VARIABILITY ESTIMATION

The five aerial surveys conducted of the 28-km index area of the Ivishak River yielded total counts ranging from 2,252 (September 17) to 2,998 (September 28) Dolly Varden (Table 1). The mean summed count for both observers over all subsections was 2,720 fish with a standard error of 133 and a CV of about 5%. Counts were generally about three or four times greater in Section 1 than in either Sections 2 or 3. Variability of summed counts (both observers) was different among sections, and was least variable in Section 3. Observer 1 (left bank) usually counted less fish than observer 2, except in Section 3 during the September 17 and 22 surveys. Summed counts for Observer 1 were slightly more variable than those for observer 2 (Observer 1 CV = 13.7%, Observer 2 CV = 12.1%)

MARK-RECAPTURE ABUNDANCE ESTIMATION

A total of 1,571 Dolly Varden were captured, measured, and marked during the first event between September 14 and September 20, 2003. Because river icing made boat travel and seining impossible near the end of the experiment, a recapture event could not be conducted in Section 3. Because of this, the mark-recapture population estimate was limited to Sections 1 and 2 only.

Table 1.-Aerial counts of Dolly Varden char in a 28 km index reach of the Ivishak River, September 2003.

Replicate date	Survey conditions	Section	Observer	Section count	Section total	Replicate total
9/17/2003	Excellent	1	1	369	1,277	2,252
			2	858		
		2	1	217	509	
			2	292		
		3	1	427	516	
			2	89		
9/20/2003	Good	1	1	836	1,833	2,893
			2	997		
		2	1	243	496	
			2	253		
		3	1	245	564	
			2	319		
9/21/2003	Excellent	1	1	813	1,904	2,848
			2	1,091		
		2	1	104	261	
			2	157		
		3	1	300	683	
			2	383		
9/22/2003	Excellent	1	1	571	1,669	2,610
			2	1,098		
		2	1	162	504	
			2	342		
		3	1	278	437	
			2	159		
9/23/2003	Excellent	1	1	328	2,187	2,998
			2	1,859		
		2	1	74	346	
			2	272		
		3	1	113	465	
			2	352		

-continued-

Table 1.-Page 2 of 2.

Summary statistics by section				
	Section 1	Section 2	Section 3	Summed counts
Mean count	1,764	423	533	2,720
Standard error	158	51	43	133
Coefficient of variation	9%	12%	8%	5%

Table 2.-Marking and recapture history from 2003 Ivishak River mark-recapture abundance experiment.

Section	No. Marked	Recaptured in Second Event Sec. 1	Sec. 2	Sec. 3	Total
1	568	38	3	-	41
2	181	2	14	-	16
3	106	0	0	-	0
All	855	40	17	-	57
		Examined in Second Event			
		Sec. 1	Sec. 2	Sec. 3	Total
Total Examined		531	185	0	716

A total of 749 fish were marked in Sections 1 and 2, and a total of 716 fish were captured and examined during the recapture event (Table 2). During the recapture event, 57 marked fish were recaptured.

Two Kolmogorov-Smirnoff two sample tests were performed to test the hypotheses of no difference between the size distributions of Dolly Varden marked on the first event (M) with those examined on the second event (C) and those marked fish recaptured on the second event (R). When using data pooled from sections one and two of the river, the null hypotheses was rejected for the M versus R test ($p = 0.032$), but the null hypothesis was not rejected for the M versus C test ($p = 0.135$). This implied that there was size selectivity during the first event, but not during the second event, indicating that the estimator used would not have be stratified by size (Table 2; Appendix A).

When the tests for consistency for the Petersen type estimator (Seber 1982) were evaluated, results indicated that the Bailey modified Petersen estimator was the appropriate model Most marked Dolly Varden were recaptured in the same section in which they were marked, and repeated aerial surveys during the mark-recapture experiment suggested there was incomplete mixing between the two sampling events. However, the null hypothesis that the probability that a marked fish was seen during the second event was independent of marking strata failed to be rejected ($p = 0.474$). Further, the null hypothesis that marked:unmarked ratios during the second event was independent of second event strata also failed to be rejected ($p = 0.474$). Estimated abundance of Dolly Varden > 220 mm was 9,259 fish (SE = 1,156) in Sections one and two of the study area.

The mean length of all fish captured was 425 mm fork length. The smallest fish captured was 220 mm fork-length and the largest was 705 mm fork-length. The length distribution of fish captured during 2003 was distinctly bimodal, with a large peak around 330 mm and a smaller peak around 540 mm (Figure 4). There were relatively few fish captured between 400 and 460 mm in length.

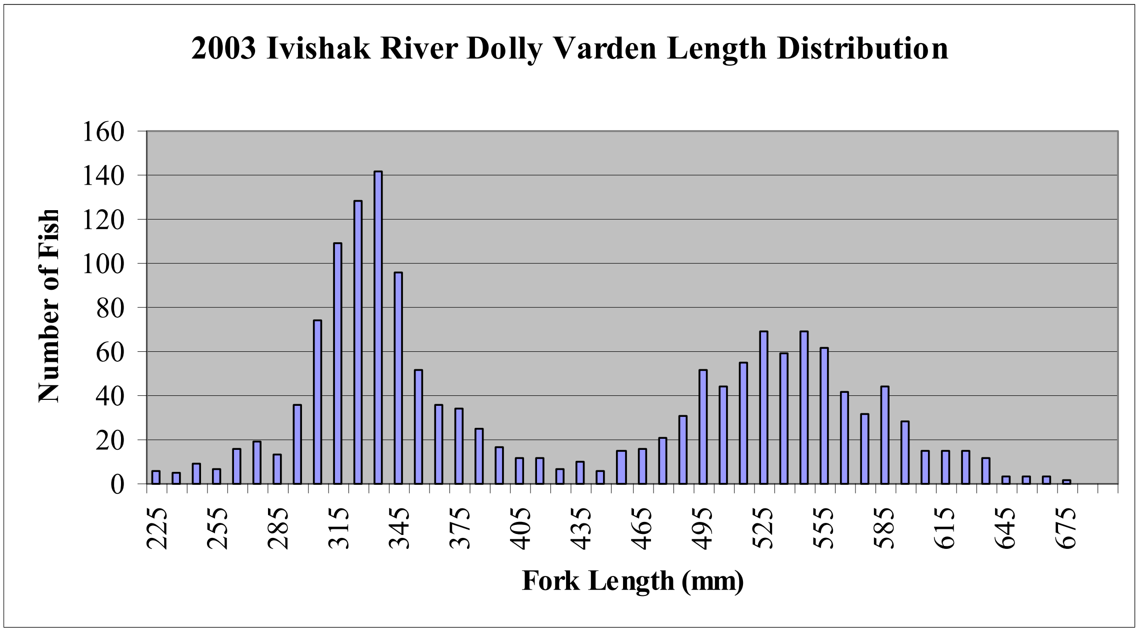

Figure 4.-Length distribution of overwintering anadromous Dolly Varden captured in the Ivishak River, September 2003 (n = 1,571).

RADIOTELEMETRY

Radio-tagged Dolly Varden in the Ivishak River were located on September 22, and 24 (Figures 5 and 6). These fish exhibited relatively little movement during that time period, although they did disperse from the implant site (NEW Figure 3). Most fish upstream of the implant site, and none of them traveled downstream into the mark-recapture area. Additionally, 13 Dolly Varden radio-tagged in September 2002 were located. Most of these fish were also located above the implant site, including one located in Flood Creek, a tributary above the index area. None of these Dolly Varden were located in the mark-recapture area. Two of the radio-tags we located remained in the same place between September 22 and 24, and we assumed these did not represent live fish.

These tags were probably either shed by live Dolly Varden or from individuals that died during the winter. One of these tags was within the index area, and one just upstream of the upper boundary of the index area. All other radio-tags located were judged to be in live fish because they moved during radio tracking, or between location dates.

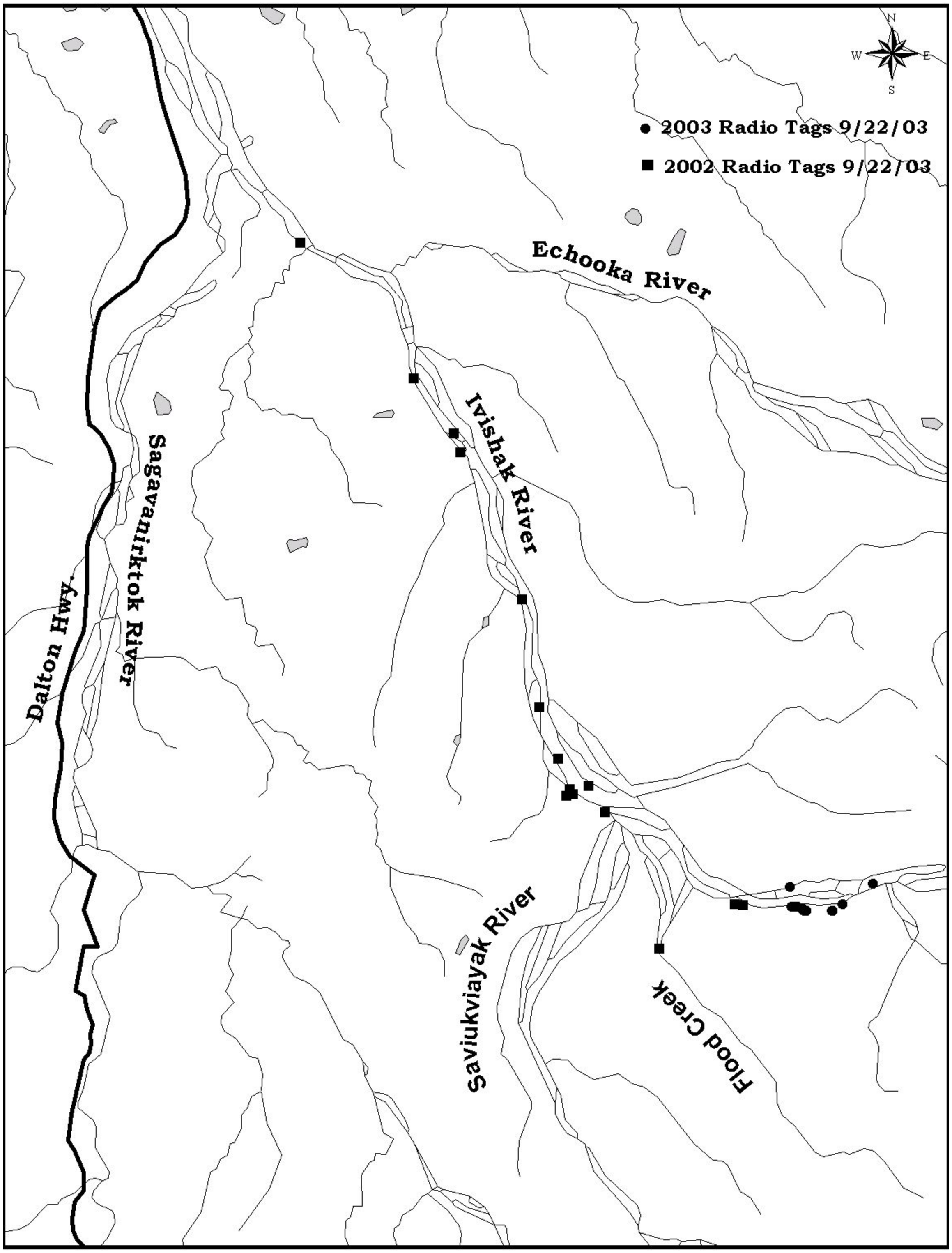

Figure 5.-Locations of radio-tagged Dolly Varden in the Ivishak River, Alaska, September 22, 2003.

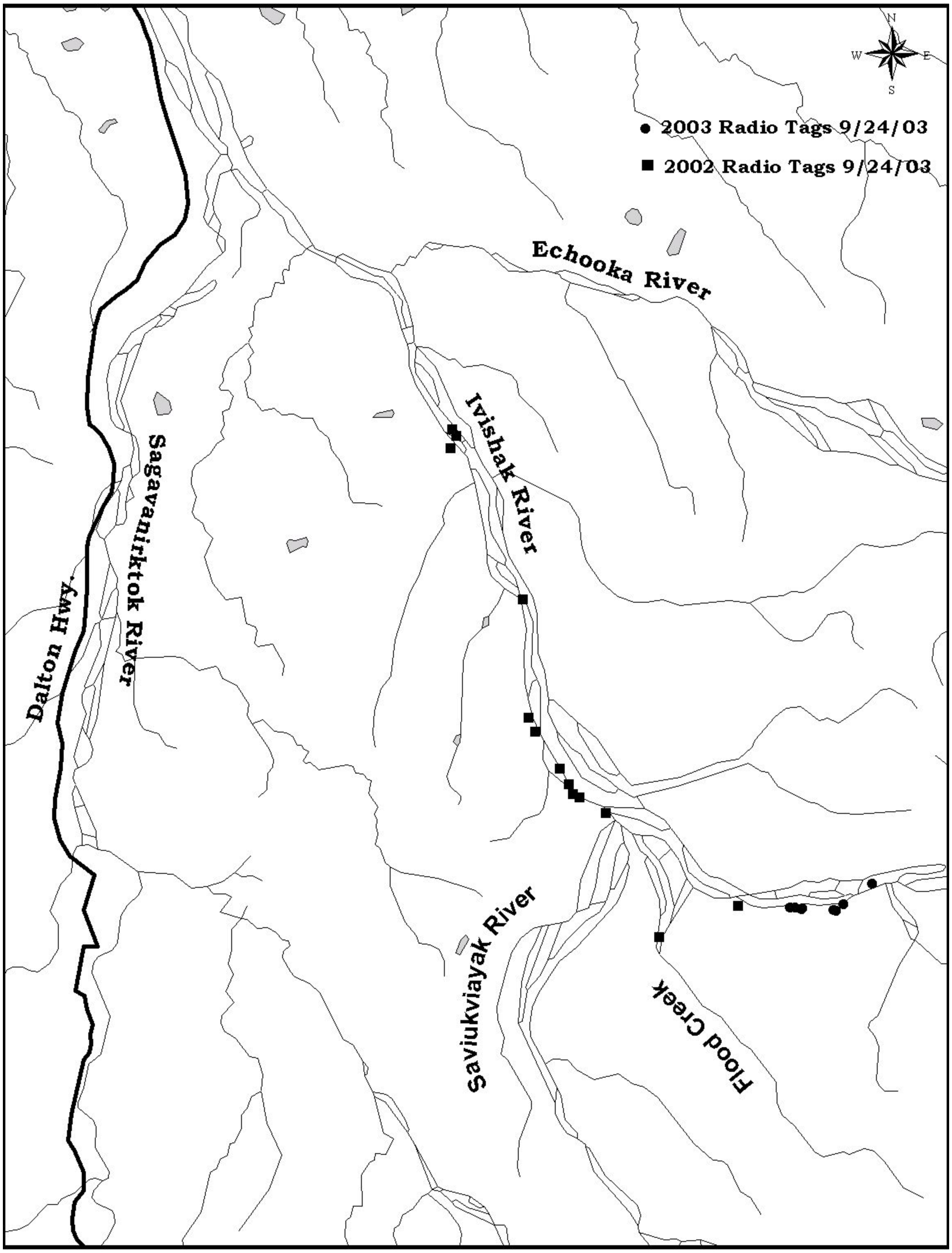

Figure 6.-Locations of radio-tagged Dolly Varden in the Ivishak River, Alaska, September 24, 2003.

Spawning and Overwintering Locations and Genetic Stock Identification Baseline Sampling

Thirty-seven discrete spawning locations were identified in the upper Ivishak River on September 14, 2003 (Figure 7 and Appendix B). Although some of these sites were in the same or nearby locations to spawning areas located in previous years of the study, a large number were located farther upstream than any previously identified spawning sites.

Overwintering areas in the Ivishak River have been determined by locating radio-tagged fish during April 2002 and 2003 (Viavant 2003; Appendix C). Additional information on overwintering areas in the Ivishak and Anaktuvuk rivers will be obtained during April 2004 surveys.

Tissue samples collected from spawning adults or pre-smolt juveniles during September, 2003 were added to existing collections from the Ribdon, Anaktuvuk, and Saviukviak rivers. In addition, a mixed-stock sample of 500 non-spawning overwintering adults was collected from the Ivishak River during the mark-recapture experiment. This mixed-stock sample will be compared with stock-specific samples to evaluate the feasibility of conducting mixed stock genetic analyses.

DISCUSSION

Aerial Survey Variability Estimation

The variability of replicate counts from all three years of our study was low, indicating that counts by the same observers are repeatable over varied conditions and a range of fish densities. The CV of the mean summed counts was 5.0%, for 2003, 6.7% for 2002, and 2.8% for 2001. In general, previous studies of aerial counts of Pacific salmon have indicated that variability increases with the density of fish being counted (Bevan 1961; Eicher 1953; Jones 1995). While we only have three years of data, we did not find a similar relationship for our Dolly Varden counts. In fact, the least variable counts were obtained during the year with greatest number of fish. Overall, variability was within a fairly narrow range all three years of the study, and was probably affected more by differences in counting conditions than by differences in fish abundance.

Aerial counts from 2001 and 2002 showed a similar pattern over time of increasing abundance in upriver sections and decreasing abundance in downriver sections over the five days that replicate

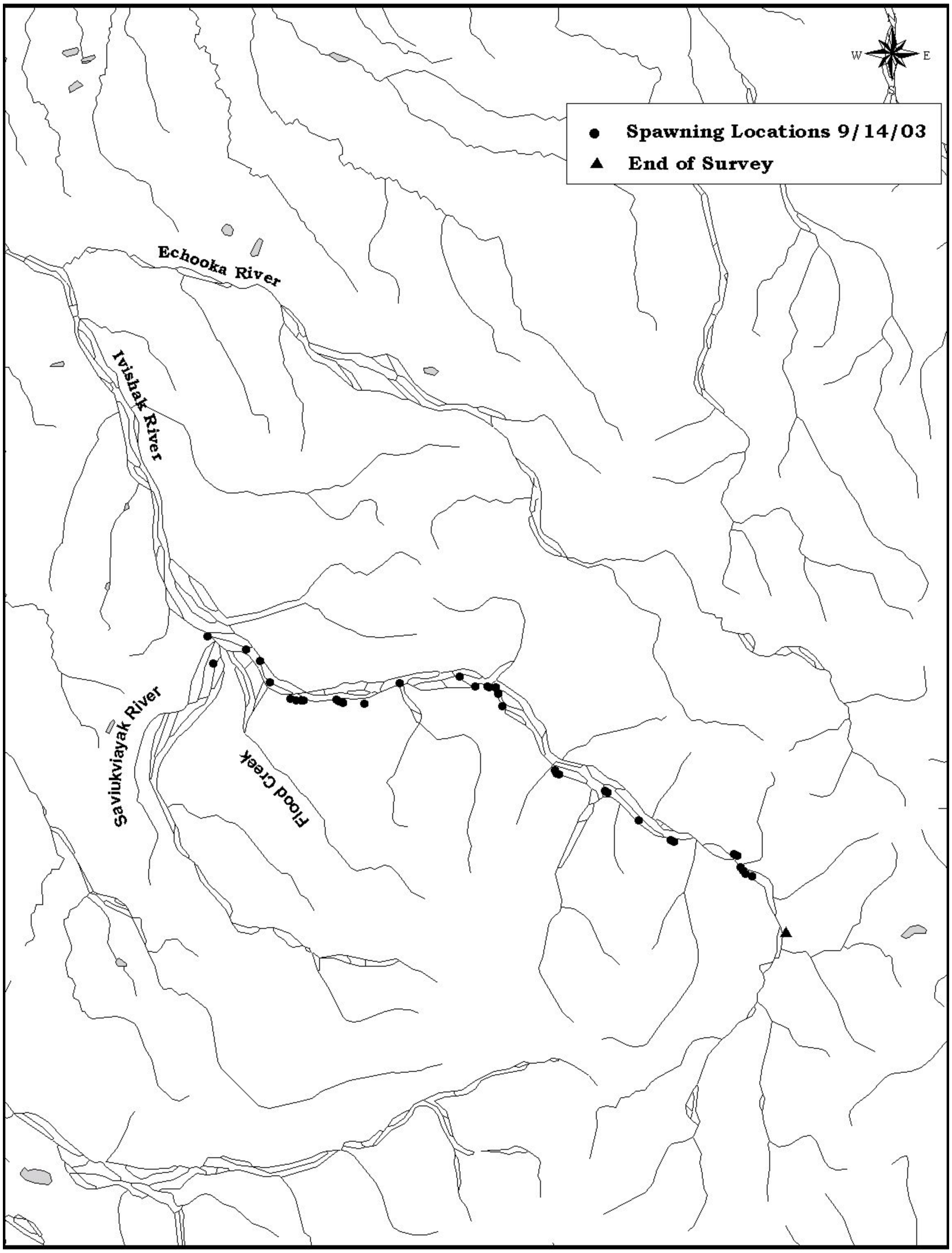

Figure 7.-Dolly Varden spawning locations in the upper Ivishak River, September 14, 2003.

counts were made. This pattern was not apparent during 2003, and may have been related to a difference in the timing of migration into the overwintering area, since air temperatures were colder and river icing occurred earlier in 2003 than in either 2001 or 2002.

The average summed aerial count from 2003 was 50.3% of the same average summed aerial count from 2002, and only 24.9% of the same count from 2001. However, because the mark-recapture estimate for 2003 was only for Sections 1 and 2 , similar comparisons between the mark-recapture estimate and aerial counts for all sections in all years was not possible. The 2003 count for Sections 1 and 2 represented 23.6% of the mark-recapture abundance estimate. This was similar to the percent of the mark-recapture estimate accounted for by aerial surveys in 2002 (25 %) and 2001 (22%) (Table 3).

Table 3.-Summed average aerial counts and mark-recapture abundance estimates of Dolly Varden in a 28 km index area of the Ivishak River, Alaska, 2001-2003.

	Summed average aerial count			Mark-recapture estimate			Aerial count
Year	Count	Standard error	CV	Abundance	Standard error	CV	percent of M/R estimate
2001	10,932	314	2.8%	49,523	7,277	14.7%	22.1%
2002	5,408	363	6.7%	21,639	3,075	14.2%	25.0%
2003	2,187[b]	131[b]	6.0%[b]	9,259[b]	1,156[b]	12.5%[b]	23.6%

[a] Coefficient of variation (standard error as percent of mean).

[b] Sections one and two of the index area only.

Taking into account the variability in both methods, the aerial surveys counted between 16 and 31 percent of the abundance as estimated by the mark recapture experiment. This compares to the 2002 aerial surveys that counted between 19 and 31 percent of the abundance as estimated by the 2002 mark recapture experiment, and the 2001 aerial counts counting between 17 and 27 percent of the 2001 mark recapture estimate. This proportion was relatively consistent over all three years, indicating that the aerial counts provided a valid index of abundance over the range of population densities encountered.

MARK-RECAPTURE ABUNDANCE ESTIMATION

Although the mark-recapture estimate for 2003 was not directly comparable to estimates from 2002 and 2001 because it only included Sections 1 and 2, it appeared to be consistent with past relationships to aerial survey counts (Table 3). Both mark-recapture and aerial survey counts indicate a decline in abundance of the overwintering population during the three years of the study. It is possible that part of this decline could be due to increasing numbers of maturing

Dolly Varden. In 2003 there were large numbers of spawning fish in the upper Ivishak and other nearby drainages that contribute non-spawning fish to the overwinter aggregation in the Ivishak River.

While the relationship between each year's mark-recapture estimate and aerial survey count was similar, the variability of mark-recapture estimates was substantially higher than that for aerial survey counts (Table 3). Although this indicates that aerial survey counts were more precise, this study and past studies have shown that aerial observers tend to undercount numbers of fish (Eicher 1953; Bevan 1961; Jones 1995; Bue et al. 1998). Biases in the mark-recapture estimate could lead to either over or underestimating abundance, depending upon how well model assumptions are met (Appendix A). Based on diagnostic testing of model assumptions, it is not likely that the mark-recapture estimate was significantly biased.

The average length of Dolly Varden sampled in 2003 was 425 mm, which was 25 mm less than the average sample length from previous years' samples. The 2003 sample length distribution was also different from that obtained in previous years (Figure 8). Because the same gear was fished in the same manner and locations in all years, these differences were not likely due to gear selectivity. Dolly Varden captured during 2003 showed a distinctly bimodal size distribution, with peaks around 330 and 545 mm. When compared with sample length distributions from previous years, recruitment into larger size classes is apparent.

The length distribution of Dolly Varden in 2003 was more similar to that reported by Yoshihara (1972 and 1973) than length distributions from either 2000 or 2001. Samples collected by Yoshihara also were bimodal, with a small peak at 325 mm. The length distribution of 2002 and 2003 samples may have been affected not only by recruitment of first-year migrants, which spent their first year at sea, to the sampling gear, but also by the large percentage of mature Dolly Varden that spawned in 2002 and 2003.

RADIOTELEMETRY

Weather and helicopter problems limited the ability of surveyors to track Dolly Varden fitted with radio tags during September 2003. The movements of the 18 fish radio-tagged fish were minimal, and no spawning fish moved downstream into the mark-recapture index area. Because radio tags were deployed late in the season and only located twice relatively soon after deployment, information collected only served to support the assumption

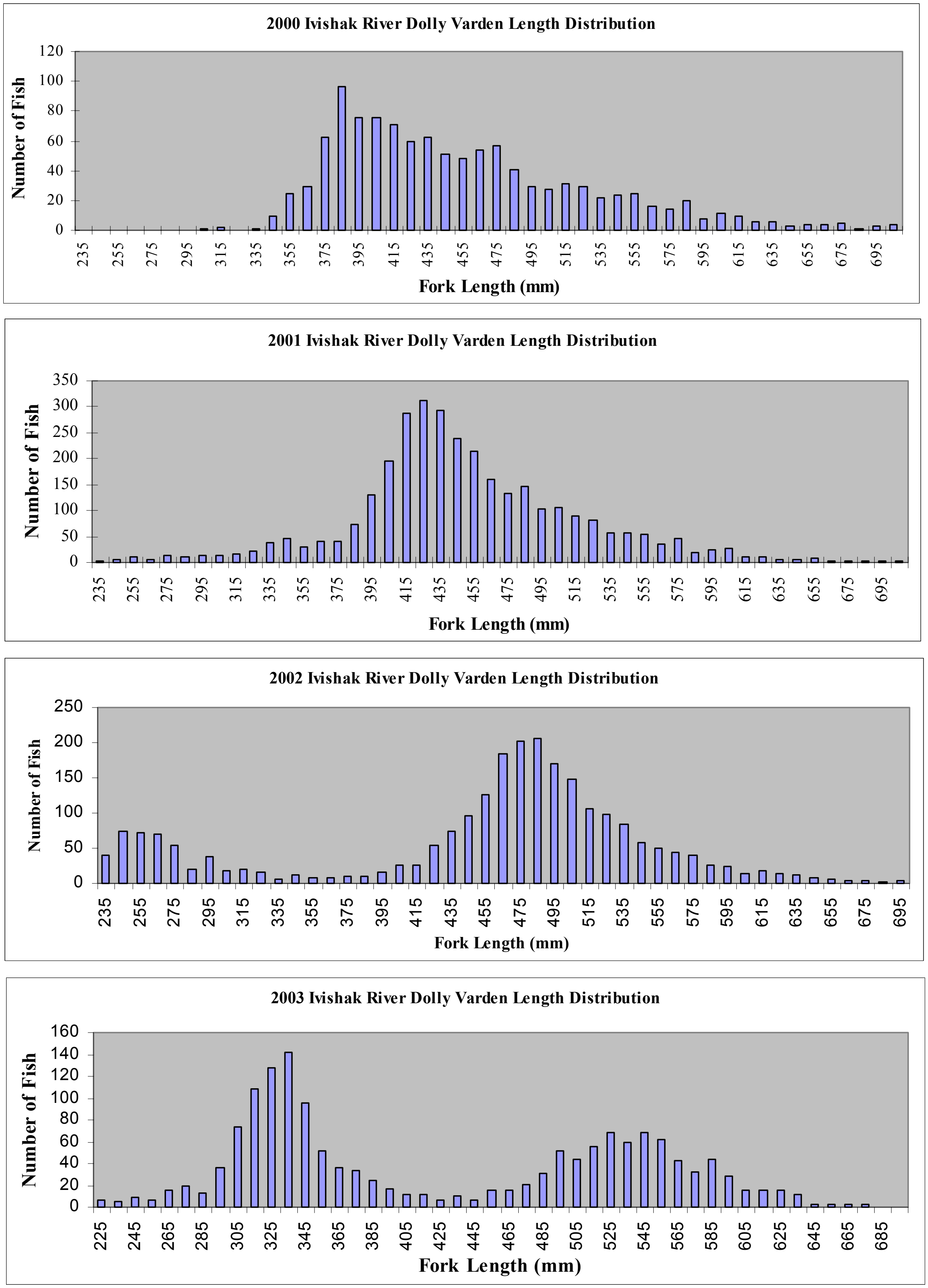

Figure 8.-Length distribution of overwintering anadromous Dolly Varden captured in the Ivishak River, September 2000 (n = 1,122), September, 2001 (n = 2,955), September 2002 (n = 2,445), and September 2003 (n = 1,579).

that very few Dolly Varden in spawning or post-spawning condition were captured during the mark-recapture experiment.

Information collected during September 2003 on 13 Dolly Varden fitted with radio tags in 2002, also supported the assumption that Dolly Varden in spawning condition did not move downstream during the mark-recapture experiment. This was also the case for radio tagged Dolly Varden tracked during 2001 and 2002. Also, no radio-tagged Dolly Varden located within the index area at the beginning of a particular study year moved out of the index area (upstream or downstream) during that year.

Spawning and Overwintering Locations and Genetic Stock Identification Baseline Sampling

The spawning abundance, location, and timing of Dolly Varden may vary considerably from year to year. The number of spawners observed in the upper Ivishak River was similar in 2003 and 2002, and there were much fewer spawners in 2001. During 2003, Dolly Varden were located in spawning areas in the Ivishak River that were substantially upstream of any previously determined (Figure 7). This has significant implications for identifying critical habitat, because a single survey year will probably not be sufficient. Finally, mature Dolly Varden captured in the Ivishak River on September 23, 2003, had not yet spawned, while all mature Dolly Varden captured by September 20, 2002 had already spawned.

Overwintering locations of Dolly Varden fitted with radio transmitted in 2003 will be determined in the Anaktuvuk and Ivishak rivers in April 2004, and all spawning and overwintering location data from the three years of this study will be documented in the final report.

As of September 2003, genetic sampling of spawning Dolly Varden has been completed for the Ivishak, Saviukviak, Echooka, Anaktuvuk, Kavik, Main Fork of the Canning, and Marsh rivers. Genetic sampling has not yet been completed for the Kongakut, Shaviovik, Ribdon, and Lupine rivers. Most of these samples have been analyzed to develop marker regions that might be used to distinguish Dolly Varden stocks among drainages or groups of drainages. If sufficient genetic differences exist among spawning stocks, as previous research suggests (Everett et al. 1997; Krueger at al. 1999), baseline data will be used to analyze mixed-stock samples from subsistence fisheries and overwintering populations. The feasibility of conducting genetic mixed stock analyses will be discussed in the final report.

CONCLUSIONS

1. Replicate aerial counts of overwintering Dolly Varden within a 28-km section of the Ivishak River had relatively low variability, and these aerial counts represented approximately 22% to 25% of the estimated abundance in the same 28-km section as measured by mark-recapture methods.
2. The overwintering abundance of Dolly Varden in Sections 1 and 2 of the 28 km index area of the Ivishak River in the fall of 2003 was 9,259 (SE = 1,156). The estimated number of Dolly Varden overwintering in this section of the Ivishak River varied by approximately 70% over a three year period.
3. The number of spawning Dolly Varden, timing of spawning, and locations used for spawning on the Ivishak River appear to vary considerably from year to year.

RECOMMENDATIONS

1. Aerial surveys of overwintering aggregations of Dolly Varden in North Slope drainages can be used as an indicator of overwintering abundance, but these surveys should be combined with surveys of spawning areas in the same drainage, since the number of spawners among the total overwintering population seems highly variable from year to year.
2. The specific locations of critical spawning and overwintering habitat used by anadromous Dolly Varden in Beaufort Sea drainages may change significantly between years within a relatively large area of a drainage. Protection of such habitat should be based on locations determined over a longer period of time (e.g., 3-5 years).
3. Spawning-stock-specific genetic samples should be collected from the remaining major Dolly Varden spawning stocks for which collections do not yet exist or are not yet complete (Nanushak, Kuparak, Aichilik, Hulahula, Lupine, Ribdon, upper Sagavanirktok, and Shaviovik rivers). Mitochondrial DNA from all baseline samples should be analyzed to establish a library of marker regions that could be compared with genetic samples from subsistence Dolly Varden fisheries on the North Slope to estimate the stock composition of those harvests.
4. Subsistence harvests of Dolly Varden in the communities of Kaktovik and Nuiqsut should be estimated for a minimum of two consecutive years, and genetic samples should be collected from those harvests to attempt to estimate the stock composition of those harvests.

ACKNOWLEDGEMENTS

I thank the U.S. Fish and Wildlife Service, Office of Subsistence Management for providing $183,600 in funding support for this project through the Fisheries Resource Monitoring Program, under agreement number 701811J333, and for constructive comments during review of the Investigation Plan. I also thank the North Slope Borough Regional Advisory Council for supporting the project, and the North Slope Borough Fish and Wildlife Management Committee and Department of Wildlife for support and assistance in project planning. I also thank the staff of the USFWS Arctic National Wildlife Refuge and the Fairbanks Fishery Resources Office for advice during planning and logistical support. Thanks to the Alaska Division of Fish and Wildlife Protection for the use of their facilities on the North Slope, and thanks to the field staff of the Alaska Department of Fish and Game for the hard work they provided in difficult working conditions.

LITERATURE CITED

Bailey, N. T. J. 1951. On estimating the size of mobile populations from capture-recapture data. Biometrika 38:293-306.

Bailey, N. T. J. 1952. Improvements in the interpretation of recapture data. Journal of Animal Ecology 21:120-127.

Bevan, D. E. 1961. Variability in aerial counts of spawning salmon. Journal of the Fisheries Research Board of Canada, 18(3):337-348.

Bue, B. G., S. M. Fried, S. Sharr, D.G. Sharp, J. A. Wilcock, and H. J. Geiger. 1998. Estimating salmon escapement using area-under-the-curve, aerial observer efficiency, and stream-life estimates: The Prince William Sound pink salmon example. North Pacific Anadromous Fisheries Commission Bulletin1:240-250.Cochran, W. G. 1977. Sampling techniques, third edition. John Wiley and Sons, New York.

Craig, P. C. 1987. Subsistence Fisheries at coastal villages in the Alaskan Arctic, 1970-1986. Minerals Management Service, Alaska OCS Socioeconomic Studies Program, Technical Report No. 129. Anchorage.

Craig, P. C. 1989. An introduction to anadromous fishes in the Alaskan Arctic. Biological Papers of the University of Alaska, 24:27-54.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241-260.

Everett, R. J., R. L. Wilmot, and C. C. Krueger. 1997. Population genetic structure of Dolly Varden from Beaufort Sea drainages of northern Alaska and Canada. Pages 240-249 in J. B. Reynolds, editor. Fish Ecology in Arctic North America. American Fisheries Society Symposium 19, Bethesda, Maryland.

Eicher, G. J. Jr. 1953. Aerial methods of assessing red salmon populations in western Alaska. Journal of Wildlife Management 17(4):521-528.

Evenson, M. J. 1988. Movement, abundance and length composition of Tanana River burbot stocks during 1987. Alaska Department of Fish and Game, Fishery Data Series No. 56, Juneau.

Jones, E. L. III. 1995. Observer variability and bias in estimation of Southeast Alaska pink salmon escapement. Masters Thesis. University of Alaska, Fairbanks. 152 pp.

Krueger, C.C., R. L. Wilmot, and R. J. Everett. 1999. Stock origins of Dolly Varden collected from Beaufort Sea coastal sites of Arctic Alaska and Canada. Transactions of the American Fisheries Society 128:49-57.

Pedersen, S. 1990. Assessment of the 1988-89 Kaktovik subsistence fishery. Internal report to US Fish and Wildlife Service. Cooperative Agreement No. 14-16-0007-88-7744. Subsistence Division, Alaska Department of Fish and Game, Anchorage, Alaska. 35 pp.

Robson, D. S., and H. A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 93:215-226.

Seber, G. A. F. 1982. The estimation of animal abundance, and related parameters, second edition. MacMillan Publishing Company, New York.

Viavant, T. 2001. Eastern North Slope Dolly Varden Spawning and Overwintering Assessment Feasibility. Federal Subsistence Fishery Monitoring Program, Final Project Report No. FIS00-002. U.S. Fish and Wildlife Service, Office of Subsistence Management, Fishery Information Services Division, Anchorage, Alaska.

Viavant, T. 2002. Eastern North Slope Dolly Varden Genetic Stock Identification and Stock Assessment. Federal Subsistence Fishery Monitoring Program, Annual Project Report No. FIS01-113-1. U.S. Fish and Wildlife Service, Office of Subsistence Management, Fishery Information Services Division, Anchorage, Alaska.

Viavant, T. 2003. Eastern North Slope Dolly Varden Genetic Stock Identification and Stock Assessment. Federal Subsistence Fishery Monitoring Program, Annual Project Report No. FIS01-113-2, U.S. Fish and Wildlife Service, Office of Subsistence Management, Fishery Information Services Division, Anchorage, Alaska.

Yoshihara, H. T. 1972. Monitoring and evaluation of Arctic waters with emphasis on the North Slope drainages. Alaska Department of Fish and Game, Federal Aid in Sport Fish Restoration. Annual Report of Performance, 1971-1972. Project F-9-4, Job G-III-A, Volume 13:1-49.

Yoshihara, H. T. 1973. Life history aspects of anadromous Arctic char (Salvelinus alpinus) in the Sagavanirktok River drainage. In Monitoring and evaluation of Arctic waters with emphasis on the North Slope drainages. Alaska Department of Fish and Game, Federal Aid in Sport Fish Restoration. Annual Report of Performance, 1972 1973. Project F-9-5, Job G-III-A, Volume 14:1-83.

APPENDIX A

Appendix A.-Mark-recapture abundance estimation methods.

A mark-recapture abundance estimate of the 28-km index area will be conducted using a Bailey modified Petersen two-event estimator. The assumptions necessary for an accurate estimate of abundance in this experiment are that (taken from Seber 1982):

1. the population will be closed (no change in the number of Dolly Varden in the population during the experiment);
2. all Dolly Varden will have the same probability of capture during the marking event or in the recapture event, or marked and unmarked fish mix completely between marking and recapture events;
3. marking of Dolly Varden will not affect their probability of capture in the recapture sample;
4. Dolly Varden will not lose their mark between the marking and recapture events; and,
5. all marked Dolly Varden will be reported when recovered in the recapture sample.

Sampling is designed (short overall study duration and short sampling hiatus) to lessen risks associated with assumption 1. The 28-km study area will be sampled in 8-10 days which will reduce the likelihood of natural mortality. The likelihood and effects of migration cannot be totally assured, particularly with fall-run Dolly Varden, however, the experiment will not begin until after aerial surveys indicate that there are no fish below the assessed area, which will indicate the migration upstream is complete. This assumption will also be partially examined through comparison of the marked-to-unmarked ratios in the lowermost sampled area (subject to immigration from downstream areas), and examination of catch patterns relative to the upstream and downstream sampling locations. Additionally, evaluation of movement patterns of radio-tagged fish will also be used to assess the validity of this assumption.

The hypothesis that fish captured during the marking sample have the same length frequency distribution as fish captured in the recapture sample will be tested. There are four possible outcomes of these two tests; either one or both of the samples are biased or neither are biased. Possible actions for data analysis are outlined in Appendix Table 1. Results of this test will address the validity of assumption 2 and 3 in relation to unequal catchability by length.

Because capture probabilities can differ significantly among areas, assumption 2 will also be examined using the three tests of consistency described by Seber (1982). If one of the three tests is not significant than an unstratified Bailey modified Petersen estimator will be used to estimate abundance. If there is movement between areas, but all three of the

Appendix Table A1.-Methodologies for alleviating bias due to size selectivity by means of statistical inference.

	Result of first K-S test [a]	Result of second K-S test [b]
Case I [c]		
	Fail to reject H_o	Fail to reject H_o
	Inferred cause: There is no size-selectivity during either sampling event.	
Case II [d]		
	Fail to reject H_o	Reject H_o
	Inferred cause: There is no size-selectivity during the second sampling event, but there is during the first sampling event.	
Case III [e]		
	Reject H_o	Fail to reject H_o
	Inferred cause: There is size-selectivity during both sampling events.	
Case IV [f]		
	Reject H_o	Reject H_o
	Inferred cause: There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

[a] The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H° for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H° for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling event for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Estimate length and age distributions from second event and adjust these estimates for differential capture probabilities.

consistency tests are significant, then a Darroch (1961) estimator will be used. If no movement between subsections of the index area occur and all these tests are significant then a stratified Bailey modified Peterson estimate will be used after testing for consistency and length bias between strata (see Seber 1982, section 3.1.2, pages 61-62).

In the unlikely event that substantial movement completely out of the index area (and by inference movement into the index area) occurs between the mark and the recapture event then the modified Petersen-Bailey estimator of Evenson (1988) will be used (given the results of the other assumption tests described here and the assumptions of this method as described in Evenson 1988). In this case the capture-recapture data will be reorganized into three equal area sub-sections prior to hypothesis testing and analysis.

The last two assumptions are validated by the sampling methods used. Assumption 4 is assured because all fish are marked by a partial finclip, which cannot grow back during the study. Assumption 5 is assured by careful examination of all fish for finclips.

The modified Petersen estimator of Bailey (1951, 1952) is used to estimate abundance:

$$\hat{N} = \frac{n_1(n_2+1)}{(m_2+1)} \tag{1}$$

where:

$\hat{N} =$ abundance of Dolly Varden in the Ivishak River study area;

n_1= number of Dolly Varden marked and released during the first event;

n_2= number of Dolly Varden examined for marks during the second event; and,

m_2= number of Dolly Varden recaptured in the second event.

Variance of this estimator is calculated by (Bailey 1951, 1952):

$$V[\hat{N}] = \frac{(n_1)^2(n_2+1)(n_2-m_2)}{(m_2+1)^2(m_2+2)}. \tag{2}$$

Length Composition in Mark-Recapture Assessment

Testing of assumptions necessary for accurate abundance estimation may also reveal biases in length composition samples. Unequal catchability by length may bias estimates of length composition. Length composition is used to apportion the population estimate into length classes; length information collected during either the marking sample, the recapture sample, or both samples will be used to calculate length composition, depending on the tests described in Appendix Table 2.

If case I (Appendix Table 2) from inference testing occurs, no adjustments to length data will be necessary and data from both events will be pooled. If case II occurs, only length data from the recapture event will be used to estimate composition. If the population is closed between sampling events the abundance estimate is germane to both sampling events. For these two scenarios the proportion of fish at length is calculated as:

$$\hat{p}_k = \frac{y_k}{n} \tag{3}$$

where:

$\hat{p}_k$ = the proportion of Dolly Varden that are within length class k;

n_k = the number of Dolly Varden sampled that are within length class k and,

n = the total number of trout sampled.

The variance of this proportion is estimated as (from Cochran 1977, page 52):

$$\hat{V}[\hat{p}_k] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1}\left(1-\frac{n}{\hat{N}}\right) \tag{4}$$

If case III from inference testing occurs, both mark and recapture samples are biased. If case IV occurs the recapture sample is biased and the status of the mark sample is unknown. If case III occurs, length data from both samples will be pooled and adjustments made to these data. If case IV occurs and the stratified and unstratified abundance estimates are dissimilar, length data from the recapture sample will be used to estimate composition. These data must also be adjusted for bias due to length-selectivity. To adjust length data, the proportion of fish in each length class is calculated by summing independent abundances for each length class and then dividing by the summed abundances for all length classes. First the conditional proportions from the sample are calculated:

$$\hat{p}_{ik} = {}^{n_{ik}}\!/\!_{n_i} \tag{5}$$

where:

n_i = the number sampled from length strata *i* in the mark-recapture experiment;

n_{ik} = the number sampled from length class *k* that are within length strata *i*; and,

$\hat{p}_{ik}$ = the estimated proportion of fish in length class *k* within length strata *i*.

The variance calculation for $\hat{p}_{ik}$ is identical to equation 4 (with appropriate substitutions).

If stratification is necessary, length and age proportions of proportions for Dolly Varden will be estimated using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}} \hat{p}_{ik} \tag{6}$$

The variance of $\hat{p}_k$ is approximated using the Delta method (Seber 1982) by:

$$\hat{V}[\hat{p}_k] \approx \sum_{i=1}^{j} (\hat{p}_{ik} - \hat{p}_k)^2 \frac{\hat{V}[\hat{N}_i]}{\hat{N}^2} + \sum_{i=1}^{j} \left(\frac{\hat{N}_i}{\hat{N}} \right)^2 \hat{V}[\hat{p}_{ik}] \tag{7}$$

where: $\hat{N}_i$ = the abundance of Dolly Varden in stratum *i*; and

$\hat{N}$ = total abundance of Dolly Varden.

SAMPLE SIZE

The sample sizes for the entire mark-recapture experiment will be determined according to Appendix Table 2, depending roughly on the number of fish counted in the index area during initial aerial surveys. Assuming that aerial surveys typically underestimate the number of fish present in the assessed areas, the population size used will be assumed to be approximately 100% higher than the number counted during the aerial survey immediately preceding the marking event. Sample size was determined according to procedures outlined by Robson and Regier (1964). Ideally, the total sample size for each event will be apportioned to each of the three sub-sections according to the relative abundance within each section.

Appendix Table A2.-Sample sizes needed to meet objective criteria for abundance estimate of spawning/overwintering aggregation within the Ivishak River.

Aerial survey count just prior to marking event is within		Assumed population Size	Number to mark during 1st event	Number to examine for marks during 2nd event	Population marked or examined during the 2nd events	Expected number of recaptured fish during 2nd event	Expected number of unique fish examined
55	166	500	136	136	27.2	37	235
167	277	1,000	209	209	20.9	44	374
278	388	1,500	266	266	17.7	47	485
389	499	2,000	315	315	15.8	50	580
500	832	2,500	358	358	14.3	51	665
833	1,388	5,000	529	529	10.6	56	1,002
1,389	1,943	7,500	660	660	8.8	58	1,262
1,944	2,499	10,000	771	771	7.7	59	1,483
2,500	3,055	12,500	869	869	7.0	60	1,678
3,056	3,610	15,000	958	958	6.4	61	1,855
3,611	4,166	17,500	1,040	1,040	5.9	62	2,018
4,167	4,721	20,000	1,116	1,116	5.6	62	2,170
4,722	5,277	22,500	1,187	1,187	5.3	63	2,311
5,278	6,110	25,000	1,255	1,255	5.0	63	2,447
6,111	7,221	30,000	1,381	1,381	4.6	64	2,698
7,222	8,332	35,000	1,497	1,497	4.3	64	2,930
8,333	9,443	40,000	1,604	1,604	4.0	64	3,144
9,444	10,555	45,000	1,706	1,706	3.8	65	3,347
10,556	11,666	50,000	1,801	1,801	3.6	65	3,537
11,667	12,777	55,000	1,892	1,892	3.4	65	3,719
12,778	13,888	60,000	1,979	1,979	3.3	65	3,893
13,889	14,499	65,000	2,063	2,063	3.2	65	4,061
15,000	17,778	70,000	2,143	2,143	3.1	66	4,220

APPENDIX B

Appendix B.-North Slope Dolly Varden spawning locations.

River	Date	Longitude (degrees)	Longitude (minutes)	Longitude (decimal minutes)	Latitude (degrees)	Latitude (minutes)	Latitude (decimal minutes)	Approximate number of fish
Kongakut	8/17/00	142	3	09	69	2	43	60
	8/17/00	141	59	54	69	4	45	75
	8/17/00	141	59	39	69	5	16	50
	8/17/00	141	58	46	69	5	44	90
	8/17/00	141	57	53	69	5	47	100
	8/17/00	141	56	55	69	6	06	40
Ivishak	9/24/00	147	43	04	69	2	04	120
	9/24/00	147	42	18	69	1	51	160
	9/24/00	147	35	57	69	2	32	85
	9/20/02	147	53	52	69	04	40	20
	9/20/02	147	52	88	69	03	82	40
	9/20/02	147	52	283	69	03	01	10
	9/20/02	147	55	61	69	05	97	10
	9/20/02	147	58	73	69	05	79	60
	9/20/02	147	59	22	69	05	76	110
	9/20/02	148	00	49	69	05	83	300
	9/20/02	147	52	10	69	02	98	15
	9/20/02	147	49	76	69	02	36	25
	9/20/02	147	48	64	69	02	25	135
	9/20/02	147	47	48	69	01	84	20
	9/20/02	147	43	17	69	02	04	125
	9/20/02	147	42	69	69	01	91	200
	9/20/02	147	48	12	69	02	23	30
	9/20/02	147	47	96	69	02	25	20
	9/20/02	147	40	320	69	01	91	50
	9/20/02	147	39	22	69	01	73	15
	9/20/02	147	20	96	69	01	13	35
	9/14/03	148	0	42	69	5	82	160
	9/14/04	147	55	23	69	4	98	12
	9/14/04	147	59	95	69	4	45	6

-continued-

Appendix B.-Page 2 of 5.

River	Date	Longitude (degrees)	Longitude (minutes)	Longitude (decimal minutes)	Latitude (degrees)	Latitude (minutes)	Latitude (decimal minutes)	Approximate number of fish
	9/14/04	147	53	50	69	4	36	45
	9/14/04	147	52	45	69	3	23	25
	9/14/04	147	49	77	69	2	31	55
	9/14/04	147	49	3	69	2	21	125
	9/14/04	147	47	98	69	2	18	15
	9/14/04	147	48	36	69	2	19	15
	9/14/04	147	43	51	69	2	3	6
	9/14/04	147	43	14	69	1	97	130
	9/14/04	147	42	74	69	1	91	50
	9/14/04	147	42	61	69	1	86	60
	9/14/04	147	39	72	69	1	72	30
Ivishak	9/14/04	147	34	57	69	2	55	40
	9/14/04	147	34	57	69	2	55	6
	9/14/04	147	26	27	69	2	59	30
	9/14/04	147	24	24	69	2	3	9
	9/14/04	147	22	62	69	1	95	4
	9/14/04	147	22	39	69	1	91	30
	9/14/04	147	21	51	69	1	90	40
	9/14/04	147	21	25	69	1	55	10
	9/14/04	147	20	83	69	0	90	4
	9/14/04	147	14	52	68	57	39	44
	9/14/04	147	14	31	68	57	25	22
	9/14/04	147	14	2	68	57	19	10
	9/14/04	147	7	95	68	56	10	12
	9/14/04	147	7	67	68	56	3	10
	9/14/04	147	3	79	68	54	47	10
	9/14/04	146	59	66	68	53	30	30
	9/14/04	146	59	26	68	53	21	12
	9/14/04	146	51	24	68	52	25	27

-continued-

Appendix B.-Page 3 of 5.

River	Date	Longitude (degrees)	Longitude (minutes)	Longitude (decimal minutes)	Latitude (degrees)	Latitude (minutes)	Latitude (decimal minutes)	Approximate number of fish
	9/14/04	146	50	91	68	52	16	6
	9/14/04	146	50	62	68	51	56	6
	9/14/04	146	50	27	68	51	36	8
	9/14/04	146	50	5	68	51	19	41
	9/14/04	146	49	12	68	51	2	13
Shaviovik	9/21/02	147	45	21	69	48	75	150
Echooka	9/19/01	147	59	80	69	24	42	40
	9/19/01	147	54	90	69	23	40	30
	9/19/01	147	50	96	69	23	16	40
	9/19/01	147	28	79	69	16	46	45
	9/19/01	147	30	16	69	16	98	50
	9/19/01	147	27	12	69	16	17	45
	9/19/01	147	24	85	69	16	09	50
	9/19/01	147	23	46	69	16	13	35
	9/20/01	147	22	83	69	16	07	150
	9/20/01	147	25	79	69	15	95	35
	9/20/01	147	19	89	69	15	65	50
	9/20/01	147	19	22	69	15	62	45
	9/20/01	147	12	72	69	11	62	40
Saviukviak	9/16/01	148	01	07	69	03	19	35
	9/16/01	148	02	62	69	02	55	40
	9/16/01	148	07	90	68	57	22	35
	9/16/01	148	04	09	68	53	18	25
	9/19/02	148	08	36	68	59	77	40
	9/19/02	148	08	27	68	57	34	30
	9/19/02	148	09	25	68	58	69	15
	9/19/02	148	08	24	68	59	78	20

-continued-

Appendix B.-Page 4 of 5.

River	Date	Longitude (degrees)	Longitude (minutes)	Longitude (decimal minutes)	Latitude (degrees)	Latitude (minutes)	Latitude (decimal minutes)	Approximate number of fish
	9/19/02	148	08	27	68	59	36	20
	9/16/03	148	7	6	68	55	57	10
	9/16/03	148	7	98	68	57	20	75
	9/16/03	148	8	35	68	59	86	50
	9/16/03	148	7	73	68	0	39	15
	9/16/03	148	6	98	68	0	62	10
Ribdon	9/17/02	147	48	73	68	39	34	50
	9/17/02	147	48	69	69	02	23	25
	9/17/02	148	16	42	68	38	38	25
	9/17/02	148	13	10	68	38	17	15
	9/17/03	147	48	99	68	39	27	10
	9/17/03	147	59	98	68	38	51	8
	9/17/03	148	16	64	68	38	42	10
	9/17/03	148	17	35	68	38	50	15
Lupine	9/18/02	148	14	54	68	52	41	20
	9/18/02	148	12	83	68	51	29	25
	9/18/02	148	14	54	68	52	41	35
	9/16/03	148	14	5	68	52	14	12
	9/16/03	148	12	97	68	51	38	7
Kavik	9/19/03	69	30	9	146	37	41	15
	9/19/03	69	28	47	146	36	36	10
	9/19/03	69	28	22	146	36	9	20
	9/19/03	69	27	97	146	35	88	15
	9/19/03	69	27	81	146	35	90	25
	9/19/03	69	25	73	146	34	45	35
	9/19/03	69	30	10	146	37	29	15
	9/19/03	69	30	19	146	37	12	80

-continued-

Appendix B.-Page 5 of 5.

River	Date	Longitude (degrees)	Longitude (minutes)	Longitude (decimal minutes)	Latitude (degrees)	Latitude (minutes)	Latitude (decimal minutes)	Approximate number of fish
	9/19/03	69	29	32	146	37	46	30
	9/19/03	69	31	87	146	38	1	30
Kavik	9/19/03	69	31	87	146	39	21	20
	9/19/03	69	32	34	146	39	33	25
	9/19/03	69	32	28	146	39	55	65
	9/19/03	69	33	29	146	39	75	50
Anaktuvuk	9/20/02	68	52	32	151	08	52	20
	9/20/02	69	03	17	151	07	02	35

APPENDIX C

Appendix C.-Ivishak River Dolly Varden overwintering locations.

		Implant					Overwintering				
Frequency	River	Date	Location				Date	Location			
148.013	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	6.56	148	3.21
148.023	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	5.31	147	55.7
148.034	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	7.04	148	3.99
148.043	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	10.09	148	5.76
148.053	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	14.77	148	8.54
148.062	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	6.42	148	2.81
148.072	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	Fish not located			
148.083	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	6.56	148	3.21
148.093	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	19.82	148	12.66
148.103	Ivishak	9/15/2001	69	10.13	148	5.64	4/16/2002	69	7.21	148	1.84
148.114	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	12.8	148	5.07
148.124	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	17.49	148	8.98
148.134	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	12.78	148	5.01
148.144	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	24.23	148	14.53
148.153	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	6.46	148	3.18
148.163	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	24.23	148	14.53
148.174	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	7.11	148	4.28
148.184	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	6.31	148	2.3
148.194	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	24.4	148	15.46
148.204	Ivishak	9/15/2001	69	15.14	148	8.83	4/16/2002	69	10.05	148	5.15
148.213	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	11.9	148	5.12

-continued-

Appendix C.-Page 2 of 4.

		Implant					Overwintering				
Frequency	River	Date	Location				Date	Location			
148.223	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	14.76	148	8.74
148.233	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	20.22	148	13.39
148.242	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	24.23	148	14.53
148.255	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	19.82	148	12.66
148.263	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	6.54	148	2.96
148.273	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	17.34	148	8.92
148.285	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	13.66	148	7.58
148.293	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	6.44	148	2.92
148.304	Ivishak	9/15/2001	69	19.28	148	11.1	4/16/2002	69	16.86	148	9.03
148.315	Ivishak	9/15/2001	68	57.23	148	7.9	4/16/2002	Fish not located			
148.323	Ivishak	9/15/2001	68	57.23	148	7.9	4/16/2002	69	3.24	148	1.10
148.334	Ivishak	9/15/2001	68	57.23	148	7.9	4/16/2002	69	1.9	148	4.83
148.344	Ivishak	9/15/2001	69	2.58	147	34.57	4/16/2002	69	2.42	147	36.5
148.354	Ivishak	9/15/2001	69	2.58	147	34.57	4/16/2002	69	6.51	148	3.18
148.362	Ivishak	9/15/2001	69	2.58	147	34.57	4/16/2002	69	2.04	147	25.72
148.374	Ivishak	9/15/2001	69	19.58	148	11.77	4/16/2002	69	25.07	148	17.1
148.384	Ivishak	9/15/2001	69	19.58	148	11.77	4/16/2002	69	8.51	148	5.27
148.393	Ivishak	9/15/2001	69	19.58	148	11.77	4/16/2002	69	19.04	148	10.77
148.404	Ivishak	9/15/2001	69	19.58	148	11.77	4/16/2002	69	13.18	148	5.97
148.423	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	17.82	148	8.99
148.433	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	14.43	148	8.00

-continued-

Appendix C.-Page 3 of 4.

Frequency	River	Implant					Overwintering				
		Date	Location				Date	Location			
148.444	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	7.32	148	4.96
148.453	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	6.59	148	2.96
148.465	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	9.5	148	5.91
148.474	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	6.51	148	3.14
148.484	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	7.62	148	4.87
148.492	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	10.86	148	5.08
148.505	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	13.05	148	5.8
148.513	Ivishak	9/15/2002	69	6.36	148	2.39	4/26/2003	69	22.49	148	15.1
148.524	Ivishak	9/15/2002	69	10.57	148	6.1	4/26/2003	69	6.9	148	3.28
148.534	Ivishak	9/15/2002	69	10.57	148	6.1	4/26/2003	69	8.63	148	5.76
148.545	Ivishak	9/15/2002	69	10.57	148	6.1	4/26/2003	69	6.59	148	2.96
148.555	Ivishak	9/15/2002	69	10.57	148	6.1	4/26/2003	69	16.68	148	9.35
148.563	Ivishak	9/15/2002	69	10.57	148	6.1	4/26/2003	69	14.05	148	7.35
148.573	Ivishak	9/15/2002	69	12.46	148	4.81	4/26/2003	69	14.31	148	8.13
148.586	Ivishak	9/15/2002	69	12.46	148	4.81	4/26/2003	69	11.09	148	5.27
148.594	Ivishak	9/15/2002	69	12.46	148	4.81	4/26/2003	69	7.45	148	4.72
148.603	Ivishak	9/15/2002	69	12.46	148	4.81	4/26/2003	69	7	148	4.2
148.611	Ivishak	9/15/2002	69	12.46	148	4.81	4/26/2003	69	17.5	148	8.77
148.62	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	7	148	4.2
148.629	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	11	148	5.6
148.641	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	14.21	148	8.3

-continued-

Appendix C.-Page 4 of 4.

		Implant					Overwintering				
Frequency	River	Date	Location				Date	Location			
148.652	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	9.06	148	6.02
148.66	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	9.48	148	5.9
148.668	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	13.23	148	5.63
148.682	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	10.97	148	6.15
148.69	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	17.5	148	8.77
148.7	Ivishak	9/15/2002	69	14.91	148	8.97	4/26/2003	69	7	148	4.2
148.711	Ivishak	9/15/2002	69	14.91	148	8.97			0		0
148.719	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003	69	13.23	148	5.63
148.731	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003	69	6.59	148	2.96
148.743	Ivishak	9/15/2002	69	19.58	148	11.77			0		0
148.751	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003	69	22.27	148	14.87
148.76	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003		0		0
148.772	Ivishak	9/15/2002	69	19.58	148	11.77			0		0
148.78	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003	69	14.21	148	8.3
148.79	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003	69	8.95	148	6.02
148.81	Ivishak	9/15/2002	69	19.58	148	11.77	4/26/2003	69	6.73	148	3.4

The U.S. Fish and Wildlife Service, Office of Subsistence Management conducts all programs and activities free from discrimination on the basis of sex, color, race, religion, national origin, age, marital status, pregnancy, parenthood, or disability. For information on alternative formats available for this publication please contact the Office of Subsistence Management to make necessary arrangements. Any person who believes she or he has been discriminated against should write to: Office of Subsistence Management, 3601 C Street, Suite 1030, Anchorage, AK 99503; or O.E.O., U.S. Department of Interior, Washington, D.C. 2040.